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INLAND FISHERIES MANAGEMENT

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23. TROUT LAKE MANAGEMENT

David P. Borgeson

HABITAT CONSIDERATIONS

It is beyond the scope of this paper to discuss at length the limnolog of trout lakes and the habitat preferences of lake-dwelling trout. Howeve the manager should consider the following basic concepts before deciding whether or not a lake should be managed with trout.

First, since fish grow fastest near the top of their temperature tole ance range, a lake that can be managed with either trout or warmwater fish probably better suited to trout. Many of the world's best trout producers fertile, relatively warm lakes which could (or do) support warmwater speci

Fisheries managers tend to be pessimistic in evaluating what is or is trout water from temperature and oxygen data. Trout can survive for one o two days in 80° F. water and have been known to survive for two weeks at temperatures of 73-74° F. (Eipper, 1964; Eipper and Regier, 1962). The duration of high temperatures must be known to evaluate trout habitat. Hi mid-day temperatures every day for a month need not kill trout if the wate cools night and morning. Spring areas, of course, can allow trout surviva in otherwise unsuitable habitat. In barren lakes, trout should be tried before warmwater species, if there is some doubt, simply to avoid the cost chemical treatment.

Second, trout are lower on the food chain than bass, so a lake manage with trout will generally produce more pounds of game fish than when manag with bass.

Third, the cost of trout stocking (usually necessary every year in borderline waters) should be taken into account when comparing the merits of warm-water and trout management.

SPECIES

Individual lakes are often well suited to several species of trout. Consideration of such factors as probable spawning success, angling vulnerability and popularity can lead to a number of choices, depending upon the geographic area and the individuals making the choice. Often two or more species can be tried to see which one works out best, or to add variety to the catch. It is impractical to set up criteria for choosing the correct species under all situations so, instead, the following guidelines are suggested:

1. Brown trout are usually much less vulnerable to angling than rainbow or brook trout (Eipper, 1964; H. D. Boles, unpublished).

2. Brown trout and lake trout are generally more piscivorous than either rainbow or brook trout.

3. Brook and brown trout can spawn successfully over seepage areas in lakes (Wales and Borgeson, 1961; H. D. Boles, unpublished).

4. Lake trout are lake spawners.

5. Variety enhances angler satisfaction.

6. Lake trout usually require specialized angling techniques and, pound for pound, are not the game fish brooks, browns, and rainbows are.

See the chapters on individual species for additional management information.

THE EFFECTS OF COMPETITION ON TROUT SURVIVAL AND GROWTH

In lakes physically suitable for trout, the factor that most profoundly affects trout survival and growth is competition.

An important part of fisheries management in major trout areas of North America is the chemical control of fish populations in competition with trout. Though costly, it is usually justified by greatly improved angling, especially where complete kills are realized.

Generally, the most serious competitors of trout have similar living requirements but are more prolific. Zilliox and Pfeiffer (1956), working on Adirondack lakes, and Eschmeyer (1938), on small Michigan lakes, concluded that yellow perch were more serious competitors of brook trout than other species present. Larkin and Smith (1954) observed that, with few exceptions, angling for Kamloops trout, Salmo gairdnerii kamloops, became very poor following the introduction of redside shiners into British Columbia lakes. Most of California's rough fish problems stem from populations of suckers, tui chubs, redside shiners, and squawfish. Kokanee, though not a rough fish, often become established in a lake at the expense of trout (see chapter 37). These examples illustrate the great variety of species that compete with trout. Th list could be made much longer since virtually all species living in combina- tion with trout compete with them to some extent. The importance of intraspe- cific competition will be brought out later.

A common but dangerous generalization is that a good forage fish is neede to sustain a healthy trout population where big fish are desired. Although a good forage fish is occasionally an asset to a trout fishery, the opposite is more often true.

Examples of the correlation between big trout and forage fish are legion and undeniable. But trouble lies in the blind acceptance or hazy interpreta- tion of this relationship.

One interpretation is that trout grow faster and larger on a fish diet - yet hatchery feeding tests will not bear this out. Another explanation is that big trout need a sizeable food item. But trout will not grow more by eating a one-pound item than by eating 16 weighing one ounce each, or 160 weighing 0.1 ounce each <u>unless</u> the bigger food item is easier to catch than a equivalent of smaller items. <u>Food availability is the key to fast growth</u>. (Water temperature is important also, but managers have little control over this.)

When trout grow rapidly, it can be assumed that their food, whatever it m be, is readily available. This simple explanation of good growth has univers application. It accounts for the fast growth of Kamloops trout following the introduction into barren British Columbia lakes. (Trout over 40 pounds were caught a few years after this introduction.) It explains the reduced growth rates observed in these same lakes when natural spawning increased trout num and a subsequent size increase when trout numbers were drastically reduced through competition with the introduced redside shiner (Larkin and Smith, 19 It explains the stunting of brook trout in mountain lakes and largely accoun for the familiar correlation between big water and big fish.[1/]

After a forage fish like the redside shiner invades a trout-only lake, i typically dominates the diet of large trout.[2/] It is true that these pisci rous trout usually grow faster than their predecessors but, unforunately, <u>t numbers typically plummet after the forage fish are introduced</u>.

[1/] Recruitment is less likely to saturate a large body of water than a small one, due to the size of the water and to the fact that it is more likely contain competing species; hence, the population of trout is usually more sparse in relation to its food supply. In addition, angling mortality is usually less in big waters which allows its trout to reach larger size by living longer.

[2/] The size at which trout switch to a fish diet varies with the trout and forage species but it is normally between 12 and 16 inches.

The diet of trout in lakes devoid of other fish is typically zooplankton, aquatic insects, other aquatic invertebrates, and terrestrial insects. Virtually all forage fish will also utilize many or all of these items. Since a good forage fish is extremely prolific, once established it consumes a major fraction of the trout's former food supply. Thus, trout too small to eat forage fish must compete with them for food. The net result is a marked reduction in the survival and often the growth rate of small trout (Larkin and Smith, 1954). Furthermore, when the trout do switch to a fish diet they ascend one level in the food pyramid. Since each added link in a food chain represents an energy loss of roughly 90 percent (Odum, 1953), trout production suffers.[3]

Thus, if trout growth is unsatisfactory in trout-only lakes, recruitment should be limited by means <u>other</u> than forage fish introductions, i.e., reduced stocking or tributary blockage. Trout <u>can</u> grow large on an invertebrate diet if trout numbers are controlled (recall the 40-pound Kamloops in British Columbia lakes).

Sometimes trout compete with other species without eating them to any extent. Such competition is obviously detrimental. If trout survival and growth are good under such conditions the introduction of a forage fish is not advisable. Chemical treatment, if chances of a total kill appear good and rare species are not endangered, is a reasonable solution.

In California's mid- and low-elevation reservoirs (which typically contain warmwater game fish, suckers, and minnows) trout appear to suffer from competition or predation throughout their life span, that is, recruitment is poor yet they never exhibit the good growth associated with abundant fish forage. Where threadfin shad have been introduced into this type of water (Pine Flat Lake, Shasta Lake) trout growth has become outstanding. Unfortunately, one can only speculate upon the effect that threadfin introductions have had on trout recruitment. The disappearance of the once strong kokanee population from Shasta Lake coincident with the threadfin boom, and the fact that California has no waters with significant populations of both species may be clues. Seeley and McCammon, in chapter 37, cite examples of kokanee severely limiting trout recruitment. One might expect that if kokanee suffer from threadfin competition, trout would too.

Often natural trout recruitment is insignificant and trout growth unsatisfactory under severe nonforage competition. If chemical treatment is infeasible, a good forage fish combined with maintenance stocking of 1- or 2-year-old trout may produce a good trout fishery in such waters. The forage fish may increase the availability of trout food by replacing some of the nonforage competition and thereby substantially improve trout growth.

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[3] If the forage fish are more efficient than trout in utilizing the annual production of invertebrate food, and are more available to large trout, the theoretical loss of trout production would be less than 90 percent. Conversely, trout recruitment may be so limited by the competition that the actual loss may exceed 90 percent. The dynamics here are similar to those observed by Swingle (1950) among bass and bluegill.

This type of management is now being practiced successfully in Greenwo Lake, New York/New Jersey (Dietsch and Gross, 1961) and Lake Hopatcong, New Jersey (Grahame, 1961) where the alewife (Pomolobus pseudo-harengus) provid forage, and in Quabbin Reservoir, Massachusetts, where American smelt (Osme mordax) are abundant. Trout returns typically exceed 100 percent of weight stocked from these waters.

To summarize: trout survival and yield are greatest in trout-only lak The trout-only situation is highly desirable.

Food availability is the key to good growth. Trout can grow rapidly c an invertebrate diet if their numbers are controlled. If trout growth is unsatisfactory in trout-only lakes, recruitment should be limited by means other than forage fish introductions.

In mixed populations where trout growth and survival are satisfactory complete chemical kills impossible, forage fish should not be introduced.

Where severe competition from nonforage fish inhibits trout growth, g forage fish can be an asset, especially if they pose no important threat t trout recruitment.

SURVIVAL OF STOCKED TROUT

Small fingerlings can usually be stocked in trout-only lakes with goo success. Kamloops trout stocked as fry in July have given about 5 percent returns in Lake Paul, British Columbia (Mottley, 1940) and Diamond Lake, Oregon. Three domesticated strains of rainbow stocked at 2 to 8 per ounce Diamond Lake returned about 50 percent to the angler as 0.9-pound trout (O State Game Commission, Annual Report, 1964).

At Castle Lake, Siskiyou County, 20 percent returns are consistently obtained from August plants of 2-inch (20/oz.) fingerling rainbows of dome cated stock (Wales and Borgeson, 1961). Eight of 10 groups of brook and r bow fingerlings (13.0 to 4.3/oz.) returned between 20 and 50 percent from Packer Lake (Boles et al., 1964).

Returns of 1.2 to 2.6/ounce rainbow fingerlings from June Lake, Mono County, averaged 45 percent, while those stocked at 13.5/pound returned 48 percent (Curtis, 1941). Thirty-six percent of the brook trout fingerling (3- to 5-inch) stocked in Tidy's Lake, Ontario, were caught as 8- to 13-ir trout (Harkness, 1941).

October-planted brook trout fingerlings of wild and domestic strains returned 37 to 52 percent from Stillwater Pond, New York (Green, 1952).

Near 100 percent survival is sometimes obtained when fingerlings are stocked in barren or newly treated waters (Eschmeyer, 1938; Zilliox and Pfeiffer, 1956).

Returns of 3- to 4-inch (2 to 6/oz.) rainbows from Beardsley Reservo: Tuolumne County (author's unpublished data), which contains a population o: suckers and hitch, have exceeded 25 percent.

In general, larger trout (6- to 12-inch) must be stocked in waters con-
ning substantial numbers of competing or predatory species to obtain satis-
tory returns. For example, brook and brown trout fingerlings (as large as
z.) stocked in Sardine Lake, Sierra County (Boles and Borgeson, 1966), gave
ignificant returns while about 70 percent of catchable-sized browns were
ght. The lake contained large populations of suckers and brown trout.
er lakes in California where large trout must be stocked are Crowley Lake,
e Tahoe, Lake Almanor, Eagle Lake, and Spaulding Reservoir. All contain
peting and predatory species. The important trophy trout fisheries of Lake
d Oreille, Idaho (Jeppson, 1963); Greenwood Lake, New York/New Jersey
etsch and Gross, 1961); Lake Hopatcong, New Jersey (Grahame, 1961); and
bbin Reservoir, Massachusetts, are supported at least in part by plants of
or 2-year-old trout. Returns from these fish often exceed 50 percent.

Planting date has been lightly regarded compared to trout size or species
a factor in determining survival. Logic and lack of data undoubtedly under-
this attitude. However, results of the author's planting experiments at
ardsley Reservoir and the literature review they prompted indicate that
anting date can influence survival greatly. Results of eight plants of
ngerling rainbows (3 to 20/oz.) stocked in July, August, September, and
tober in Beardsley Reservoir revealed that percentage returns dropped
arply for each month the fish were held in the hatchery <u>even though size at</u>
<u>anting increased greatly</u>. The cost per pound in the creel of fish from these
ants more than doubled each month they were held in the hatchery after July
uly-stocked fingerlings produced a pound of trout to the creel for about
.30). Burdick and Cooper (1956) had better results from early than late
ants in Weber Lake, Wisconsin; however, their late-planted fingerlings were
aller than the summer plants. They attributed the difference in returns to
pulation changes in adult trout and the size of fingerlings stocked, but it
pears that planting date should not be discounted. Boles et al. (1964) found
at July plants of brook trout fingerlings in Packer Lake, Sierra County, were
re economical than an October plant. The July fish were smaller when stocked.
inbow fingerlings stocked in September in Castle Lake gave poor returns
mpared with those stocked in July or August (Wales and Borgeson, 1961). The
xtremely successful Diamond Lake plants cited previously were stocked in mid-
ummer. Eipper and Regier (1962) recommend against stocking trout in New York
arm ponds in midsummer because of warm water temperatures. However, none of
heir experimental plants was made between June 8 and September 18 and almost
ll were made before May 15 or after October 1 (Eipper, 1964). Eipper's
ecommended management of 600 fall fingerlings (5.6-inch) per acre put a pound
f trout in the angler's creel at a cost of roughly $7. This high cost is due
n part to a low (0.22) rate of exploitation on these waters but it still
hrows doubt on these recommendations. The results of Flick and Webster (1964)
n two Adirondack Mountain ponds indicated that the more economical mid-June
lants generally survived better and grew faster than fall fingerlings (October).

Obviously, many factors determine the optimum planting date, e.g., water
emperature, predators, size of fish available for planting, and food avail-
bility. There is much to be learned about each for various lake types.
Until more data are available, the manager should weigh all of these factors
before deciding on a planting date for a particular water.

TROUT STRAIN

Trout culturists have developed domesticated trout strains well adapte to hatchery life. These fish are easier and less expensive to raise than w strains and are typically more vulnerable to angling. They perform well ir most phases of trout stocking, especially in put-and-take programs. These factors, combined with a scarcity of field tests comparing the cost of angl provided by wild and domesticated strains have resulted in the use of domes cated stock almost to the exclusion of wild strains.

However, the available data suggest that wild strains can better cope with the wild environment. Not only do they survive better and contribute more to the creel than domesticated strains but they are more likely to rep duce (Flick and Webster, 1964; H. D. Boles, unpublished data).

This is hardly surprising. Knowledge of other domestic animals and th wild counterparts would lead one to expect it. It seems logical to expect also that the difference in the success of wild and domestic trout would b greatest where the environment is most demanding. Early results of the author's studies at Beardsley and Spaulding reservoirs with wild Kamloops rainbows and four domestic rainbow strains seem to bear this out. Beards is a good trout producer and, in some years, domesticated fingerlings give good returns as Kamloops (which, when stocked at 2 per ounce, return 20 to percent to the angler as half-pound trout). Spaulding, however, has never been productive (probably because of predation or competition) and Kamloop the only rainbow strain that has shown any promise there (5 percent return Repeated plants of four domestic strains have been utter failures.

The quality of angling provided by individual fish of either wild or domestic strain is nearly impossible for the fisheries worker to measure quantitatively. This factor should not be ignored, however. Wild trout m be recognized as being generally more desirable from the angler's standpo: than trout of domesticated strain. See chapter 25 for a further discussi of trout strains.

FORMULATING A TROUT STOCKING PROGRAM

The following is a flexible and workable approach for formulating a trout stocking program for a given lake:

1. Estimate the annual trout yield (Y) <u>expected</u> to result from stocking. making this estimate take into account the lake's trout producing pot tial, present natural production, and the expected angling effort. P tial yields can usually be roughly estimated by comparison with simil waters. Knowledge of accessibility or angling effort can be helpful this regard. A lake that is fished only a few times a year by advent hikers should not be stocked as densely as a physically similar but heavily fished roadside lake.

2. Estimate the percentage return (P) from stocked trout. This estimate should be based on results from similar waters since much variation among different types of lakes. Trout size, strain used, and plantin date are also important variables (see appropriate sections). For economy's sake be optimistic.

3. Estimate the average weight (W) of the planted trout in the catch. Since trout growth and management efficiency can be greatly influenced by planting density (see appropriate sections) the estimate of W should also be optimistic. These estimates can be used in the following equation to calculate the number of trout to stock annually (N): $N = \frac{Y}{WP}$. Stocking in alternate years should be reserved for lakes that receive light fishing pressure and annually yield half or less of their potential. Otherwise, biennial planting is likely to reduce annual yield by providing too few fish in the second year. If plants are increased to compensate for the "off" year, first-year growth and survival may suffer.

EFFICIENCY IN TROUT MANAGEMENT

In past evaluations of trout management programs, considerable importance has been placed on stocking costs and numbers of trout produced with little heed to size at recapture or angling days produced.

Size at recapture profoundly affects the cost benefit ratio of trout management.

For example, fingerlings weighing 90 per pound stocked in Beardsley Reservoir and Packer Lake, California, have returned 25 and 50 percent, respectively, to the angler (Boles et al., 1964; D. P. Borgeson, unpublished). When caught, however, the Packer Lake trout weigh only 0.1 pound, whereas those from Beardsley weigh 0.5 pound each. In terms of cost in the creel, the Packer Lake fish at $0.80 per pound are 2½ times as expensive as those from Beardsley.

At Crowley Lake, a heavily fished California reservoir, 60 percent of trout stocked in summer at 10 per pound are harvested at an average size of 1.2 pounds each ($0.15 per pound caught). If the planted trout were not protected by a closed season (August through April) during their first summer in the lake, heavy fall harvests could cut size at recapture in half and nearly double the cost of a pound of trout caught. Angling benefits would suffer a similar fate since a 1-pound trout will support at least as much angling as any 1-pound aggregate of lesser trout. The alternative - stocking more fish - is a costly one since it would necessitate significantly increasing the present allotment of 300,000 fish which could, in turn, reduce trout growth.

Zilliox and Pfieffer (1956) in working with reclaimed New York lakes found that stocking densities of 20 to 30 brook trout per surface acre produced 9- to 20-ounce trout in one year and 30- to 40-ounce fish in two years. In similar lakes stocked with 37 to 100 trout per acre, however, trout reached only 2 to 4 ounces in one year. The authors believed that doubling the stocking rates on those lakes exhibiting good growth would merely reduce the weight of trout two winters old from approximately 2 pounds to 1 pound each. This familiar inverse relationship between population density and trout growth is highly significant for the trout manager. He should stock no more trout than needed to utilize the available food efficiently. If trophy trout are desired, the lake must be stocked even more sparingly. As trout numbers increase gradually in a previously barren lake, fish production rises sharply because of outstanding growth. As trout numbers continue to increase, however, the available food becomes fully utilized. Any further increase in the trout population serves only to reduce growth until the point is reached where all food is needed for metabolism and no production occurs. This is stunting.

If stocked trout are cropped at a relatively small size (for the wat in question) serious consideration should be given to reduced stocking, s limits, bag limits, closed seasons and gear restrictions as possible mean increasing size at recapture and reducing the cost of providing angling. measures are especially applicable to rich waters with outstanding growth potential.

Sometimes the planting date and size of fish stocked can also be adj to raise the size at recapture and reduce the cost of trout in the creel. example, 4-inch fingerlings stocked in Beardsley Reservoir, Tuolumne Coun in May or June are cropped heavily in September and October as 6- to 9-in fish. By stocking 3-inch fingerlings in July the harvest can be postpone until the following year (the water has a November through April closure) which time the trout average 11 inches in length (author's unpublished da

In managing public trout waters, the manager must studiously avoid t delusion that he has any control over angling quality as measured by harv per unit effort - unless, of course, he makes it zero. He can increase t number and size of trout available for capture and thereby increase the t value of a fishery, but he cannot regulate angling effort. Regardless of number of fish available, the anglers determine how much effort will be s in harvesting them. Since trout supply rarely meets demand, an increase available trout typically causes a proportional increase in effort, so ca per unit effort remains constant (Butler and Borgeson, 1965).

The exception above - zero catch per hour - was not mentioned entire for the sake of levity. Under a zero fish limit (or a drastically reduce limit combined with a large minimum size) a relatively stable standing cr trout can be maintained over a wide range of angling effort. Since catch hour is determined primarily by the population of catchable-sized trout, manager has some control over angling quality under catch and release reg tions. Such regulations should not be considered cure-alls but neither s they be shunned. They can increase the recreational value of an overfish wild trout population and they can also reduce management costs on heavil fished planted waters. Catch-and-release regulations are a natural exten of the fishery manager's most useful tools: bag limits, size limits, and restrictions.

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24. TROUT STREAM MANAGEMENT

James W. Burns and Alex Calhoun

Less than 1,300 miles of California's 18,000 miles of trout streams receive planted trout. Wild trout thus support angling in well over 90 p cent of these waters. Their management is largely limited to habitat pro tion and improvement (see pages 40-43), range extension and protection of unique species, and establishment of the most desirable species to produc wild trout crop. Generally, habitat improvement (other than stream flow maintenance dams in the Sierra), fingerling stocking, and rough fish cont have not been effective methods for improving California stream trout po tions.

Considerable information on the ecology of California streams has c from studies at Sagehen Creek (University of California) and Convict Cre (U. S. Fish and Wildlife Service). Classical texts on stream ecology an